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FLOW OVER A BLUNT PLATE AT LOW REYNOLDS NUMBER

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ABSTRACT

This paper contains the flow characteristics over a blunt and non-blunt plate. To investigate the effect of air-intake of paraglider one blunt and one non-blunt model has been prepared. To achieve the goal of this research flow visualization, local flow velocity measurement and surface pressure measurement has been conducted. Flow visualization done by smoke wire method and flow velocity measured by hot wire anemometer method. After the investigation it has been found that that the air intake is very important to inflate the flexible wing and maintain the inner pressure during flight period at different situation and it has also vital rule to create lower pressure on the lower surface of the wing, consequently increase the lift coefficient.

Keywords: Blunt Plate, Air Intake, Flexible wing, Paraglider.

1. INTRODUCTION

A paraglider consists of numbers of flexible wing canopies in parallel with a load suspended beneath it on cables (Figure 1 shows a paraglider wing). The hole that is opened in each wing front is called air intake, which is formed using ram pressure. Because of its low speed handling qualities and versatility of application for precision aerial delivery and recovery of payloads, the paraglider has been used in many areas from leisure to more sophisticated aerial recovery. Recently, it counts upon use from such an advantage as the various spotter plane dexterity in high altitude, recovery of a payload, and substitution of a military dropping parachute. As an example, a Crew-Return Vehicles X-38 of NASA is famous, and it succeeds in fall and a dropping flight experiment.

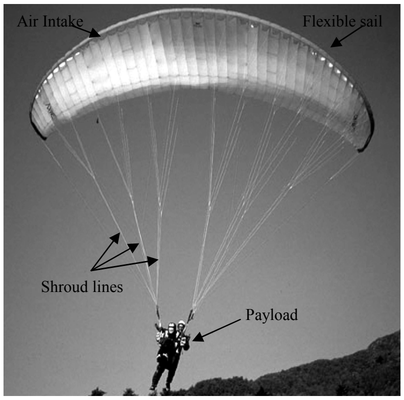


Fig. 1 Real paraglider wing

Much research has been done at NASA Johnson Space Center to describe the dynamic behavior of the paraglider and to develop guidance and control algorithms using wind tunnel tests, ground tow tests and actual aerial drop tests.

In Europe, the Institute of Flight Research of the German Aerospace Center (DLR) has conducted research to identify the dynamic behavior of a parafoil-load system and to investigate Guidance Navigation and Control (GNC) concepts. But unfortunately there is no research which has investigated the influence which intake has on the flow of the circumference of wings. In this study, research has been concentrated the attention of the characteristics of air intake, which does not exist on other wings forms even in various research targets. Air intake is the most important to secures wings form, which is located in a front wing tip part, and has great influence on the wings characteristics.

2. EXPERIMENTAL APPARATUS AND PROCEDURE

2.1 Models Description and Measuring Parameter

The experiments were conducted in a 400mm×340mm wind tunnel at Nagoya University's Aerospace Engineering Department in the Propulsion Energy Systems Engineering Laboratory. Figure 2 shows the air intake model configurations. Model was made by transparent acrylic sheet. To reduce the effect of wingtips vortex during external pressure measurement, pressure orifices were out fitted at the middle of the model. The length, pressure and velocity were made dimensionless using total measuring length *c*, uniform pressure P_∞ and uniform velocity U_∞.

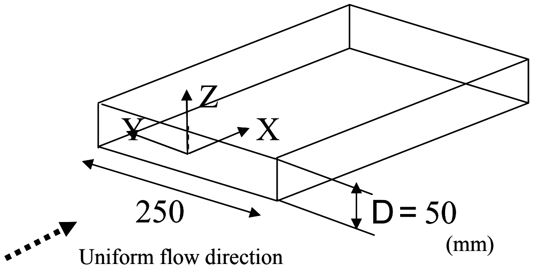


Fig. 2 Air intake model configuration.

2.2 Pressure Measurement

The static pressure along the model surface was measured by means of digital pressure gauge (model GC 15-611 manufactured by Nagano Keiki, Company Limited). Pressure orifices with 0.5 mm diameters were drilled, middle along the length, on the upper surface of the model. The upper surface of the model was outfitted 10 pressure orifices. To prevent the time lag difference of each orifice measurement, vinyl tubes of equal length were used to connect the digital pressure gauge to the orifices on the surface of the model. The pressure measured at the test section inlet was used as reference static and dynamic pressure, thus we could calculate the test section free stream velocity. To assure the high accuracy of the pressure measurement was confirmed by using different pressure measurements.

2.3 Velocity field Measurement

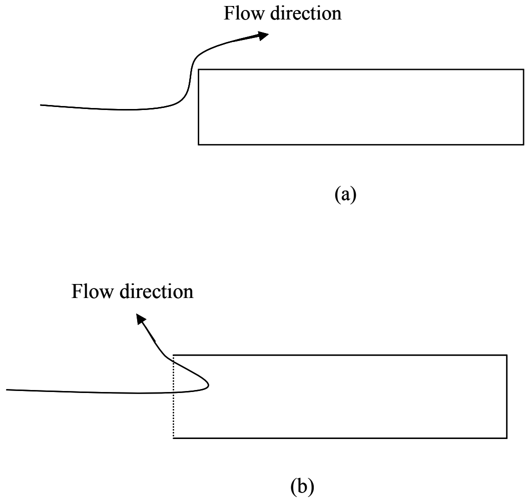
An X-probe hotwire anemometer was used to measure the flow field velocity component. The hotwire apparatus consisted of a Kanomax X-probe hotwire anemometer and Sokken hotwire flow meter model HC-30. The continuous time signals from the hotwire were digitized by an interface AD converter through a computer PCI board. A mechanical traverse system was used to move the probe over the surface of the wing along chord length. It was selected based on the size of the area to be traversed, positioning accuracy, and anticipated fluid dynamic force acting on the traverse. The hotwire anemometer measurement was conducted at fixed sampling time t= 5s and sampling frequency f= 1000 Hz. The total number of data points at each measuring point was 5000.

3. RESULTS AND DISCUSSIONS

To investigate the effects of air intake, simplified air intake model was made which is shown in Figure 2,the pressure coefficients, velocity distributions and flow visualization were investigated over the surface of the open and close air intake model which discuses below,

3.1 Flow visualization

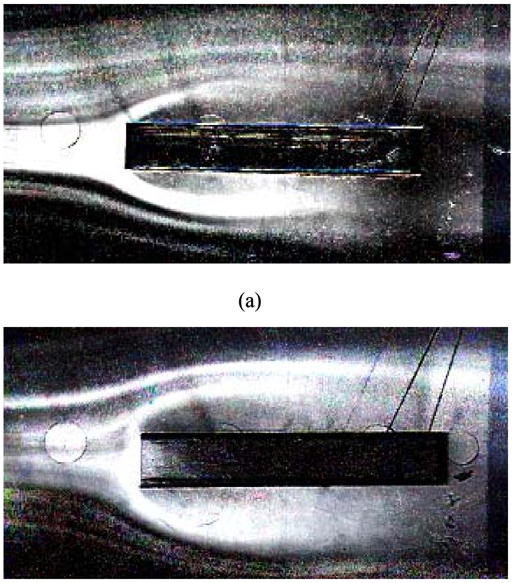
The purpose of this visualization experiment is to investigate the flow field around the air intake model and justify the hot-wire anemometer measurement of air intake model. The flow around the air intake model was visualized with smoke wire method. In this visualization experiment, the Reynolds number of the uniform flow was 20,128. For comparison, the open and close model was visualized. In these pictures the bright portions show where smoke particles are convected by the uniform stream. Thus the dark portions around the object in the pictures correspond to the separated flow regions. Comparison of these two pictures (open and close), the height of the separation zone of open system is higher than that of close system and the same result appears in the hot-wire anemometer experiment. This happens due to the direction of turning flow at the point of separation (at tip edge of the model). Though it's difficult to identify the exact location of stagnation point due to turbulences, we can gauss the nearest regions of stagnation point from the visualization picture. According to the picture, in close air intake model the stagnation point is slight front of the intake surface boundary. But in open air intake model the stagnation point is inside the intake surface boundary regions. As the stagnation point is different for the open and close system, the direction of turning flow also different and which is shown in fig 3. For close system, as the stagnation point is slightly in front of the intake surface boundary so the turning flow direction is like as fig. 3(a) which makes an acute angle with surface, consequently the height of the separation zone is low. But in open system the stagnation point is inside the model and the turning flow direction like as fig. 3(b) which makes an obtuse angle with surface compare to close system, thus it also make the higher separation zone height. From the above discussion, we can also say that the magnitude of main stream flow velocity over the separation region of open system is higher than the close system.



(a)

(b)

Fig. 3 Turning flow direction, (a) close model (b) open model



(a)

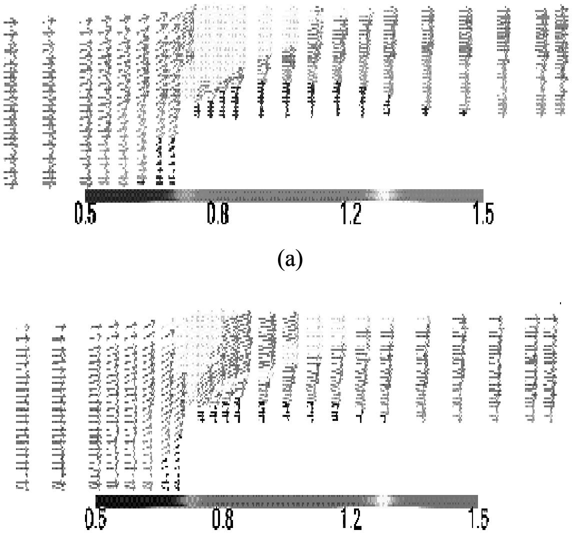
(b)

Fig. 4 Flow Visualization of air intake model, (a) close (b) open .

As, the height of the separation regions and the main stream flow velocity over the separation region is higher, of open system than close system, so the surface pressure of the open system is lower than that of close system because a fluid particle which moves in the immediate vicinity of the wall in the boundary layer remains under the influence of the same pressure field as that existing outside, because the external pressure is impressed on the boundary layer, which is shown in figure 4. The length of separation regions couldn't identify by the visualization experiment due to the lack of smoke all over the surface of the model but in our hot-wire experiment that can be traced out which is about 4.5 times of the air intake model thickness, this result consistent with the previous research of Ota and his co-workers. They have observed the character of leading edge flow at high Reynolds number. They mentioned that the turbulent separated layer reattaches to the plate at a distance of four times the plate thickness from the leading edge.

3.2 Velocity Distribution

In order to characterize the flow behavior around the air intake model an X-probe hotwire anemometer was used. X-probe hotwire anemometer has a limitation to velocity measurement over the surface due to X-probe hotwire sensor. The closest measuring position is 1 mm apart from the surface of the model. The mainstream flow velocity distribution of air intake model is shown in a Figure 5. Figure 5(a) shows the close air intake system model velocity distribution and Figure 5(b) shows the open air intake system model velocity distribution. As shown in Figure 5, almost the same flow velocity distribution was obtained both of open and close air intake system model except the nearer front tip edge portion, it is clear that the velocity of immediate next of the air intake front tip edge (upper surface) of open air intake system is higher than the close air intake system, and the velocity slope is large, too. This happens due to the change of stagnation point; the stagnation point of close air intake system is slight front of the intake surface boundary on the other hand the stagnation point of open air intake model is inside the intake surface boundary regions which was discussed in the previous section.



(a)

(b)

Fig. 5 Velocity distribution over simplified air intake model, (a) without air intake (b) with air intake.

3.3 Pressure distribution

It was also investigated a pressure distribution of the circumference of the same open and close air intake model. Using this model, the front tip part of the upper outer wall side pressure was measured, and comparison and consideration were performed. The investigation of pressure distribution result is shown in Figure 6 for a range of 0-20 degree angle of attack. In every angle of attack the pressure coefficient of open air intake system is lower than close air intake system; this is also happen due to the change of stagnation point. In open air intake system, as a result of higher magnitude and slope of turning flow velocity at the front tip edge, it causes to develop stronger vorticity in right top above of the front tip and creates lower-pressure coefficient than the close air intake system.

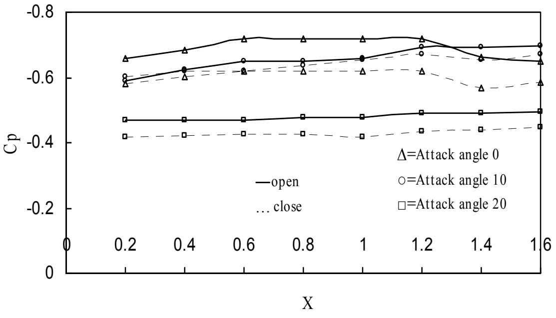


Fig. 6 Pressure distributions of simplified air intake model.

4. CONCLUSIONS

An experimental investigation of air intake of a flexible/paraglider wing for different angle of attack has been conducted. From this investigation, we can conclude that the air intake is very important to inflate the flexible wing and maintain the inner pressure during flight period at different situation and it has also vital rule to create lower pressure on the lower surface of the wing, consequently increase the lift coefficient.

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